Case Report

Heat and Moisture Exchanger Filter Causing Hypercapnoea in a Child Undergoing Surgery Under General Anesthesia

Aswani B*, Anand S**, Lailu M***
*Postgraduate, **Professor, ***Professor & HOD, Department of Anesthesiology, Chettinad Hospital and Research Institute, Chennai.

Dr Aswani is currently pursuing final year Post-Graduation in the Department of Anesthesiology, Chettinad Hospital and Research Institute. She completed her under-graduation from Chettinad Academy of Research and Education (CARE) in 2015. She has presented paper and poster in National and State level conferences. She is a Member of Indian Medical Association (IMA) Tambaram and Indian Society of Anesthesiologists (ISA) Chennai. Her area of future interest is in Regional anesthesia and Pain medicine.

Corresponding author - Aswani B (swanbkn@gmail.com)

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Abstract

The important functions of the upper respiratory tract are providing warmth, filtration and humidification of the inspired air during spontaneous ventilation. During mechanical ventilation, fresh dry gas is inhaled into the lower respiratory tract through an endotracheal tube to promote loss of moisture and heat, which leads to hypothermia causing adverse effects on the airway homeostasis. Heat and moisture exchanger filter (HMEF) was introduced to provide artificial warming and humidification. The effects of HMEF in increasing the dead space in pediatric patients have not yet been clarified. We report a case with hypercapnoea in a pediatric patient because of the HMEF which was routinely used.

Key words : Mechanical ventilation, Respiratory dead space, General anesthesia.

Introduction

During mechanical ventilation, fresh dry gas is inhaled continuously into the lower respiratory tract through an endotracheal tube which directly promotes loss of moisture and heat leading to decrease in the body temperature and adverse effects on the airway homeostasis.

Heat and moisture exchanger filter (HMEF) has been used to prevent loss of moisture and heat generated during mechanical ventilation in paediatric patients.[1]

However, increased use of HMEF leads to problems, such as accidental disconnection of the circuit, over-heating damage to the respiratory tract, pathogenic infections and increase in airway resistance owing to excessive moisture saturation in the breathing circuit, and interference with the flow-meter function.[2]

It is also known to increase dead space ventilation in respiratory distress syndromes.

However, the effect of HMEF in increasing the dead space in normal healthy pediatric patients has not yet been clarified.[3]

We report a case where hypercapnoea developed in an infant because of the HMEF which was used without considering the dead space of HMEF. The purpose of this case report is to highlight the influence of HMEF on dead space with consequent hypercapnoea and related complications in children under general anesthesia.

Case report

A 1 year old infant weighing 8.8kgs with bilateral inguinal hernia and phimosis was planned for bilateral inguinal herniotomy with circumcision under general anesthesia with caudal epidural analgesia.

Pre - anesthetic assessment revealed healthy child with no comorbidities and belonged to physical status American society of Anaesthesiologist's (ASA) classification I. The infant was premedicated with Inj.Ketamine 45mg IM and Inj.Atropine 0.2mg IM. Electrocardiography, noninvasive blood pressure, and oxygen saturation were monitored. IV access with 22G cannula was secured after induction with oxygen and sevoflurane (6%).

Endotracheal Intubation was performed using a 4.5mm inner diameter uncuffed portex endotracheal tube after administration of Inj.Fentanyl 20mcg IV and Inj.Atracurium 5mg IV and 3 vol% sevoflurane.

The position of endotracheal tube was confirmed by bilateral equal air entry on ausculation and $EtCo_2$ monitoring. The $EtCo_2$ at intubation was 25mm Hg. 100% spo_2 was maintained with 100 % Oxygen and 3% Sevoflurane on Jackson-Rees circuit.

After endotracheal Intubation, caudal epidural analgesia was administered with 0.2% Inj.Ropivacaine with Inj.Dexamethasone 1mg - total volume of 10ml. After caudal anesthesia, the patient was turned to supine position; the HMEF was attached to the endotracheal tube and connected to closed circuit.

Anesthesia was maintained on oxygen, air and Isoflurane (1%) with ventilator settings of tidal volume (VT) 72mL and respiratory rate 18 breaths/min with peak inspiratory pressure of 20 cm H_2O. After a period of 10 minutes, $EtCO_2$ waveform indicated rebreathing and was noticed that $EtCO_2$ was progressively increasing from 35mm Hg to 77mm Hg with $FiCO_2$ 0.

In order to reduce the $EtCO_2$, RR was increased from 18/min to 22/min. Bilateral equal air entry, CO_2 absorbent status, leakage in the inspiratory and expiratory tubes, moisture in the $EtCO_2$ sampling were checked and found to be normal. We also checked endotracheal tube leakage, but the tube size was appropriate and the delivered tidal volume was 70-75ml. Endotracheal suction was performed and there was no secretions.

We tried to ascertain the cause of the abnormal waveform in capnography, but no specific problem was detected.

Despite the above mentioned reasons $EtCO_2$ continued to remain high with abnormal $EtCO_2$ pattern. When re-breathing of carbon dioxide through the HMEF dead space was suspected, the HMEF, which was located close to the endotracheal tube was removed. After 10 minutes of HMEF removal, $EtCO_2$ decreased to 35 mmHg from 77mmHg with 100% SpO_2. $EtCO_2$ level was maintained from 30-35mmHg intraoperatively till the end of the surgery. The duration of surgery lasted for 1 hour 30 minutes.

Figure 1: Paediatric Heat moisture exchanger filter

Neuromuscular blockade was reversed with Inj.Glycopyrrolate 0.1mg IV and Inj.Neostigmine 0.5mg IV. Trachea was extubated after spontaneous breathing was established and the infant was awake. The infant was conscious and awake. He was shifted to the post-operative anesthesia care unit (PACU) for observation after surgery.

Post-operatively, supplemental oxygen was maintained with oxygen face mask 4L/min. The caudal epidural analgesia lasted for 7 hours. On post-operative day 1, the patient was discharged without any complications.

Discussion

The upper airway maintains humidification and protects the lungs from the environment by acting as a filter. Because mechanical ventilators with endotracheal intubation bypass the upper airway, an artificial humidifier and filter should be included in such systems.[1]

The devices for humidification include Heated Humidifiers (HH) and Heat moisture exchanger (HME).[2] HH have no dead space in the circuit but are more bulky and expensive. Conversely, HME are inexpensive and simple, but have a negative effect on ventilation because of their internal dead space volume.

Physiologic dead space is composed of alveolar dead space and anatomical dead space. The physiologic dead space is 2.2 ml/kg. This is about one third of the tidal volume. During general anesthesia, mechanical ventilation leads to added apparatus dead space. This is due to the presence of the endotracheal tube, tube adaptor, Y piece and a humidification-filter device such as an HME.

HME have a low resistance to airway flow and a relatively small volume (about 75 ml), which is not too large to impair ventilation of healthy adult patients ventilated with a tidal volume of 8-12 ml/kg.

The volume of a pediatric HME is generally 20-25 ml.[3,4]

Most pediatric patients have compliant and healthy lungs, with minimal alveolar dead space. However, the anatomical dead space of pediatric patients is larger than adult patients because the size of the head is relatively larger to their body.

Moreover, if there was a large apparatus dead space as in our case, the dead space volume could be most of the tidal volume, which resulted in ineffective ventilation and the development of hypercapnoea.

In high dead space settings, CO_2 elimination is not sufficient, even with elevated ventilatory frequencies leading to air trapping in the lungs and the development of an intrinsic positive end-respiratory pressure with consequential increases in intrathoracic pressure, reduced venous return, higher intracranial pressure and CO2 narcosis.[5]

Study conducted by Min A Kwon 2012 on the effect of a pediatric heat and moisture exchanger on dead space in healthy pediatric anesthesia concluded that the use of a pediatric HME significantly increased PaCO2 in healthy pediatric patients that was inversely proportional to weight and age.[6] The use of pediatric HME should be carefully considered in small pediatric patients.[7]

Wilkinson et al showed that the dead space increase by five types of pediatric hygroscopic HMEF filter in pediatric anesthesia was an average of approximately 12mL. Although the increase in the resistance was not statistically significant when HMEF was completely soaked with water, the important thing is the fact that the work of breathing increases because of resistance of filter in infants.

The use of HMEF should be totally restricted in a child < 2 years undergoing elective surgery under general anesthesia to avoid the increase in dead space leading to hypercapnoea and consequent complications.[8]

Conclusion

The clinicians should keep in mind that HMEF causes complications, such as mechanical occlusion of breathing circuit by the filter and respiratory acidosis with hypercapnoea by apparatus dead space rebreathing for surgeries in patients < 2years of age.

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